NOxStar™ Plant Demonstration

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NOxStar ™ is a novel post-combustion process that can achieve NO_x reduction levels of at least 70% (at ammonia slip levels of less than 5 ppm) in steam generators firing coal, natural gas and oil. The process continuously injects controlled quantities of an ammonia-based reagent with relatively minute amounts of hydrocarbon (typically either natural gas or propane) into the convective pass of an operating boiler. The injection grid comprises a permanent array of feed lances attached to the pendant heat transfer assemblies in the upper furnace gas pass. This arrangement optimizes reagent distribution throughout the NO_x-bearing flue gas mass. At the existing elevated temperatures the hydrocarbon auto-ignites to form a plasma of free radicals which autocatalyses the reaction of ammonia and NO_x to harmless nitrogen (N_2) and water vapor (H_2O).

The NOxStar ™ concept for boiler application was first validated during Q1 2001 in Mitsui Babcock's 0.55 million Btu/hr (160kW$_t$) coal-fired test facility using a single injection point. As a result of near ideal mixing NO_x reduction levels of up to 90% were achieved within acceptable ammonia slip limits.

In Q4 2001 further process validation was achieved in Mitsui Babcock's Multi-fuel Burner Test Facility (MBTF) when firing coal at a rate of 135 million Btu/hr (40 MW$_t$). A series of tests were conducted using eight fifteen feet long lances, containing multiple spray nozzles. The results were very positive and tracked the earlier performance achieved in the smaller test facility Also demonstrated was the ability to control reagent injection to localized regions of the flue gas pass. The injection lances were virtually identical to those required for a full-scale installation. (Note that these results were presented at the 2002 DoE SCR/SNCR Conference)

The NOxStar ™ process was demonstrated at TVA's Kingston 9 power plant in Q2 2002. This coal-fired boiler is a 200 MW$_e$ tangentially fired unit with twin furnaces (superheat and reheat), each having three elevations of burners supplied by six pulverizers.
The injection grid comprises twenty-two lances subdivided into nine control zones in each of the superheater and reheater passes. These nine zones allow NO_x reduction and ammonia slip to be optimized on a zone-by-zone basis to account for variability in the flue gas temperature and flow profiles at the reagent injection plane. Each water-cooled lance was fed with a controlled stream of reagent, steam and propane to satisfy the flue gas conditions at the time. Reagent rates were controlled to keep ammonia slip below 5ppm.

The results of the Q2 testing showed that NO_x levels were reduced by 68% from the baseline while maintaining an ammonia slip of 4.2 ppm or less as measured at the economizer outlet using wet chemistry techniques. Air staging in the combustion zone had contributed to this overall reduction. Alone, the NOxStar™ system had reduced NO_x levels by 53%. This was somewhat less than had been anticipated based on the earlier test rig work, however, the reasons were well understood. The test results from both test rigs demonstrated that the NO_x reduction potential was clearly a function of the flue gas temperature at the injection point, coupled with the retention time downstream of the lances. Results from both the 0.55 million Btu/hr test facility and the 135 million Btu/hr combustion test rig demonstrated this temperature dependence. Similarly, the time at temperature was also shown to influence the NO_x reduction percentage.

The flue gas temperatures at Kingston (as measured by an HVT – high velocity thermocouple, with the appropriate corrections), in the region of the injection lances, was found to be lower than the optimum. Based on test results from the MBTF combustion rig facility the NO_x reduction percentage would increase by 14%, absolute, had these temperatures been at a more optimum range. Given the close correlation between the two facilities at the lower temperature levels, it is reasonable to presume that had the injection lances been installed in a higher temperature environment the improved level of performance would have been achieved at the plant.

The injection lances installed at Kingston were of a water-cooled, externally insulated design, having a multiplicity of nozzles along their length. They were divided into three separately controllable zones to facilitate the optimal delivery of reagent to the varied distribution of flue gas across the injection plane.

During the plant testing period for NOxStar™ process performance, it was also demonstrated that:

- The detailed design of the lance was effective in allowing three control zones along the length.
- The multi-zone control arrangement was effective in optimizing the reagent supply across the boiler gas pass and was able to accommodate the significant flue gas temperature and flow distribution variation at the injection plane.
- The repeatability of the NOxStar™ process was demonstrated
- The nozzles did not plug
- The external insulation and cladding system on the lances was robust and effective
- The NOxStar™ process is readily retrofitable to utility boilers

Following the demonstration at Kingston 9, Mitsui Babcock is currently installing the first commercial installation at the Colbert 4 TVA plant. These are $200MW_e$, front wall fired, twin division wall, natural circulation, balanced draught, two pass, Carolina type boilers utilising flue gas re-circulation for superheat and reheat temperature control. Each boiler has three rows of six burners with two pulverizers supplying alternate burners on each row, for a total of six pulverizers. A simplified steam-cooled lance design has been developed for this installation. The integrity and performance of this new lance design has been demonstrated in further tests at our MBTF facility and the system will be installed during a November outage. The operating results from this installation will be available in Q1 2004.